Stillwater Sciences

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Memorandum

Date: September 13, 2006
To: Dennis Gathard, Gathard Engineering Consulting, Seattle, Washington
From: Yantao Cui, Ph.D., Hydraulic Engineer
Re: Klamath River Dam Removal – Reevaluation of Stillwater 2004 Preliminary Simulation Results

1. Introduction

In May 2005 Stillwater Sciences submitted a technical report titled "A preliminary evaluation of the potential downstream sediment deposition following the removal of Iron Gate, Copco, and J.C. Boyle Dams, Klamath River, CA" to American Rivers (Stillwater Sciences 2004), which detailed the assumptions, analysis, and conclusions regarding potential sediment deposition downstream of Iron Gate Dam following dam removal. Due to the limited information available at the time of that study and the objectives of the analysis, several "worst-case-scenario" assumptions were employed so that the predicted thickness of sediment deposition downstream of Iron Gate Dam following dam removal reflects the maximum possible thickness of deposited sediment.

This memorandum reexamines the assumptions made during the 2004 analysis in comparison with the most recent estimate of sediment release following dam removal to determine if the predicted thickness of sediment deposit downstream of Iron Gate Dam presented in Stillwater Sciences (2004) can still be viewed as the worst-case-scenario estimate. This memorandum, however, does not provide reviews to the proposed dam removal alternative and the estimated sediment release associated with the dam removal alternative.

2. Most recent estimate of sediment release following dam removal

The most recent estimate of sediment release following dam removal was provided by Mr. Dennis Gathard on September 6, 2006 via e-mail and telephone conversations. Mr. Gathard's estimate was based on information acquired through drilling and a proposed dam removal scenario briefly described below:

- Remove Copco 2 first. There is little sediment in the reservoir, so it does not need to be accounted for.
- Lower J.C. Boyle Reservoir and begin dam removal.
- Drill holes in the base of Copco 1 to provide a low-level outlet. The hole would be sized to control the rate of reservoir lowering. The average rate of reservoir lowering is assumed to be 1 ft/day.

- Lower Iron Gate Reservoir through the low-level tunnel at a rate of approximately 1 ft/day simultaneously with the lowering of Copco 1 Reservoir.
- Begin lowering the reservoirs sometime in the fall. Once the reservoirs reach their lowest levels, which is projected to take a maximum of 120 days, the demolition work on dam removal would begin. Copco will be removed completely, which may take 3 to 4 months if blasting and drilling methods are used. The removal of Iron Gate will take longer, but can be removed completely with the protection of a coffer dam.
- Remove the coffer dam above the Iron Gate Dam site approximately 1 year after the start of the removal process that would release the sediment still trapped behind the coffer dam.
- For calculating sediment release, Mr. Gathard assumed 200-ft-wide channels with 1:10 (V:H) side slopes in both Copco 1 and Iron Gate reservoirs.

Mr. Gathard estimated that the removal of Copco 1 will result in the release of 98,000 cubic yards of gravel, 419,000 cubic yards of sand, and 1,717,000 cubic yards of silt and clay, which will be distributed across the width of the Iron Gate Reservoir. Independent of the sediment released from the removal of Copco 1, Mr. Gathard estimated that the removal of Iron Gate will result in the release of 220,000 cubic yards of gravel, 451,000 cubic yards of sand, and 2,234,000 cubic yards of silt and clay. Mr. Gathard reasoned that because the estimated sediment release from Iron Gate Reservoir, without considering the sediment from the removal of Copco 1, represents 34% of the total sediment deposit in Iron Gate Reservoir, approximately 34% of the sediment released from Copco 1 will continue to transport downstream of Iron Gate Dam during and following Iron Gate Dam removal while the residual 66% would remain stored in Iron Gate Reservoir in the remnant terraces and other storage units. A brief summary of Mr. Gathard's estimate is provided below in Table 1.

Table 1. Estimated sediment release (in 10^3 yd^3) following dam removal provided by Mr. Dennis Gathard (personal communication)

	Gravel	Sand	Silt/Clay	Total
Sediment release to Iron Gate Reservoir from the removal of Copco 1	98	419	1,717	2,234
Copco 1 sediment that can transport to downstream of Iron Gate Dam following Iron Gate Dam removal (34% of row 2)	33	142	584	759
Release of the Iron Gate Reservoir sediment following Iron Gate Dam removal	220	451	2,340	3,011
Total sediment release to downstream of Iron Gate Dam site following Iron Gate Dam removal (sum of rows 3 and 4)	**253**	**593**	**2,924**	**3,770**

3. Comparison of the recent estimate of sediment release with 2004 analysis

The Stillwater Sciences (2004) analysis employed DREAM-1, one of the Dam Removal Express Assessment Models (Cui et al. 2006a,b), to simulate the potential sediment deposition downstream of Iron Gate Dam under a few worst-case-scenario assumptions that encouraged sediment deposition following dam removal. Here we only reexamine the assumptions with regard to sediment volume and grain size distribution, and compare those assumptions against the most recent estimate provided by Mr. Gathard and briefly discussed above in Section 2. Other worst-case-scenario assumptions made during the 2004 study and the details of the results can be found in the original reference (Stillwater Sciences 2004).

The modeling conducted in Stillwater Sciences (2004) assumed certain spatial distributions of sediment deposit thickness to allow for the flow to carve a channel through the sediment deposit following the rules set forth in DREAM-1, thus no explicit volume of sediment release was imposed on the model runs. A rough estimate of the volume of sediment released during and following dam removal predicted in the Stillwater Sciences (2004) modeling is described below, based on the understanding of DREAM-1 and information provided in the original report.

- The model assumed a trapezoidal channel with a bottom width of 150 ft and the default bank slope angle of 35° (Cui et al. 2006a). For simplicity, Stillwater Sciences (2004) provided an estimate based on a 150-ft-wide rectangular channel (i.e., assumes a slightly smaller cross section, and provides a volume estimate of sediment release that is slightly smaller than used in Stillwater Sciences 2004 modeling). Using the rectangular-channel assumption, a total of 3,400,000 cubic yards of sediment would be released downstream following the removal of Iron Gate Dam, of which 1,600,000 cubic yards are Iron Gates Reservoir sediment deposits, and 1,800,000 cubic yards are Copco 1 Reservoir sediment deposits (based on Table 5 on Page 8 in Stillwater Sciences 2004).

- For the 1,600,000 cubic yards released from Iron Gate Reservoir, the modeling assumed 30% sand and gravel and 70% silt and clay; for the 1,800,000 cubic yards released from Copco 1 Reservoir, the modeling assumed 5% sand and gravel and 95% silt and clay (based on the second bullet on Page 11 in Stillwater Sciences 2004).

- The sand and gravel was assumed to have a median size of 2.1 mm for modeling purposes (based on Figure 21 on Page 28 in Stillwater Sciences 2004), all of which was allowed to be released downstream unsorted during and following the removal of Iron Gate Dam, which can potentially be deposited in the downstream reach.

Based on the above information, an approximation of the volume of sediment released, as simulated in the Stillwater Sciences (2004) modeling analysis, is given below in Table 2. As noted previously, the estimated volume in Table 2 should be slightly smaller than the simulated sediment release in Stillwater Sciences (2004) worst-case-scenario modeling exercise.

Table 2. An estimate of sediment released (in 10^3 yd^3) following dam removal in the preliminary analysis of Stillwater Sciences (2004)

	Sand and gravel[a]	**Silt/Clay**[b]	**Total**
Copco 1 sediment that transports to downstream of Iron Gate Dam following Iron Gate Dam removal	90	1,710	1,800
Release of the Iron Gate Reservoir sediment following Iron Gate Dam removal	480	1,120	1,600
Total sediment release to downstream of Iron Gate Dam site following Iron Gate Dam removal (sum of rows 3 and 4)	**570**	**2,830**	**3,400**

a. All of the sediment in the sand and gravel range was assumed to be released downstream simultaneously without sorting during and following dam removal as a worst-case-scenario assumption of the modeling exercise.

b. Assumed to be transported downstream as suspended sediment without re-deposition.

In comparing the numbers in Tables 1 and 2, it is important to note that the initial sediment transport that can potentially result in sediment deposition downstream of Iron Gate Dam will in fact be particles primarily in sand range, because the gravel components is less mobile and so its transport will lag by a significant, although difficult-to-quantify, degree, and silt and clay will be transported downstream as suspended load without deposition. Thus, initial sediment deposition during Iron Gate Dam removal and immediately following the removal of the Iron Gate cofferdam in the following year should overwhelmingly comprise only the 593,000 cubic yards of sand in Table 1. This is the volume of sediment that we expect to potentially result in significant sediment deposition. For the Stillwater Sciences (2004) analysis, it is important to realize that the modeling did not directly simulate what would be most likely to occur following dam removal. Instead, the modeling provided an estimate of what might be the maximum downstream deposition that could potentially occur following dam removal under a few worst-case-scenario assumptions. One of these worst-case-scenario assumptions was that both sand and gravel would be transported downstream simultaneously as an unsorted mix during and following dam removal. Comparing Tables 1 and 2, it can be found that the combined gravel and sand release in Mr. Gathard's most recent estimate is 846,000 cubic yards, which is approximately 50% higher than the gravel and sand volume used in the Stillwater Sciences (2004) simulation. However, because the gravel will be transported downstream lagging behind sand, the amount of sediment released during Iron Gate Dam removal and immediately following the removal of the Iron Gate cofferdam will constitute primarily sand, or 593,000 cubic yards from Mr. Gathard's estimate in Table 1. This estimate is almost identical to the 570,000 cubic yards of sediment release used in the Stillwater Sciences (2004) modeling, as summarized in Table 3.

Table 3. Comparison of the volume and grain size of sediment release during Iron Gate Dam removal and immediately following Iron Gate cofferdam removal

	Volume (10^3 cubic yards)	Median Size
Mr. Gathard's most recent estimate	593	~ < 1 mm
Stillwater Sciences (2004) worst-case-scenario modeling	570	2.1 mm

In addition to the comparable volumes of predicted released sediment in Mr. Gathard's most recent estimate and Stillwater Sciences (2004) modeling for the period that includes Iron Gate Dam removal and immediately following the removal of the Iron Gate coffer dam, the median size used for the Stillwater Sciences (2004) modeling is significantly coarser than the actual grain size of the sediment most likely to be released during this period of the project. This assumption makes the modeling results even more conservative in terms of downstream sediment deposition, because there would have been less sediment deposition predicted in Stillwater Sciences (2004) modeling if a finer grain size was used.

To briefly summarize, the volume of sediment release assumed in Stillwater Sciences (2004) modeling is almost identical to Mr. Gathard's estimated sediment release for the period of Iron Gate Dam removal and immediately following the removal of the Iron Gate coffer dam; and the Stillwater Sciences (2004) modeling assumed a coarser sediment release during this period, further ensuring the conservativeness of that modeling. With that, we conclude that the Stillwater Sciences (2004) modeling results can still be viewed as worst-case-scenario results in terms of downstream sediment deposition. The above conclusion is made independent of several other worst-case-scenario assumptions made for the Stillwater Sciences (2004) modeling, which further ensure that the Stillwater Sciences (2004) results remain to be worst-case-scenario estimate. It can be expected that some or all of the worst-case-scenario assumptions can potentially be reexamined if new information that favors downstream sediment deposition is discovered.

References

Cui, Y., Braudrick, C., Dietrich, W.E., Cluer, B., and Parker, G. (2006a) Dam Removal Express Assessment Models (DREAM), Part 2: Sample runs/sensitivity tests. *Journal of Hydraulic Research*, 44(3), 308-323.

Cui, Y., Parker, G., Braudrick, C., Dietrich, W.E., and Cluer, B. (2006b) Dam Removal Express Assessment Models (DREAM), Part 1: Model development and validation. *Journal of Hydraulic Research*, 44(3), 291-307.

Stillwater Sciences (2004) A preliminary evaluation of the potential downstream sediment deposition following the removal of Iron Gate, Copco, and J.C. Boyle Dams, Klamath River, CA. *Final Report* prepared for American Rivers, 409 Spring Street, Nevada City, CA 95959, May, 34pp.